# RADIAL GOLDEN ANGLE FAST SPIN ECHO: A HYPERPOLARIZED $^{13}$C MULTI CONTRAST METOD

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**Introduction:** The $^{13}$C-labeled hyperpolarized agents, urea and HP001, have unique abilities for angiographic and perfusion studies and recently for renal ion gradient investigations [1,2]. Radial imaging using the golden angle, 111.25°, has been utilized for free breathing MR and has successfully been used for $^{3}$He MR of lungs [3], where the longitudinal $T_1$ relaxation and RF calibration yields quantitative difficulties. We propose a radial FSE approach for $^{13}$C-labeled hyperpolarized MRI, using the golden angle, 111.25°, taking advantage of the inherent off-resonance robustness in FSE sequences [4], to show the intravascular distribution and transport of hyperpolarized $^{13}$C tracers in the kidney and its relaxation mechanisms. Further, we used the center of k-space readout for motion compensation.

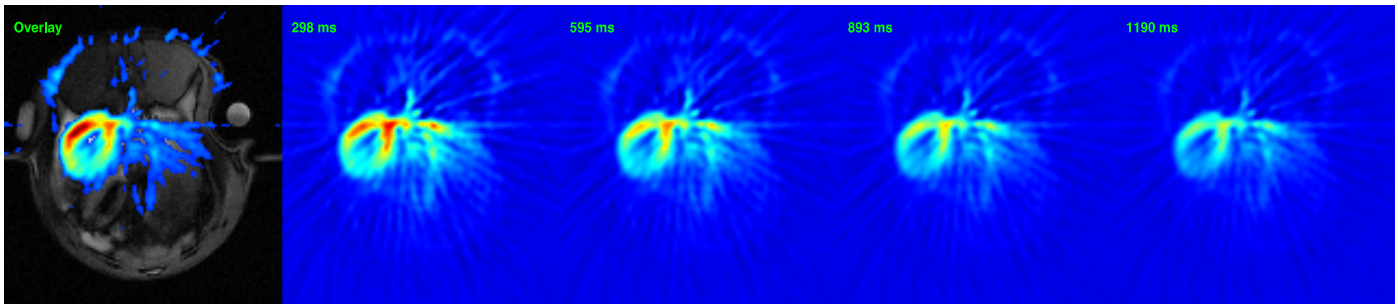


**Figure 1:** (left) HYPR $^{13}$C urea concentration, overlaid on an anatomical $^{1}$H image. (Right) HYPR high temporal images, 50 ms timepoints, 4 different points on the T2 decay curve, reflecting the hyperpolarized decay of $^{13}$C urea in the kidney cortex.

**Materials and methods** Four eight-week-old healthy male Wistar rats (210-230 g) were anesthetized with isoflurane (0.8% isoflurane, 0.25 L/min oxygen, and 0.75 L/min air). Tail vein catheterization (Ø=0.4 mm) was performed prior to administration of hyperpolarized [$^{13}$C]urea (80 mg of 8 M [$^{13}$C]urea in water:glycerol was dissolved in 4 mL phosphate buffer), and the animal was placed in a 4.7 T small-bore Agilent MR scanner equipped with an Agilent Direct Drive console with Vnmrj 2.3A Agilent Technologies, Santa Clara, CA, USA (originally supplied by Varian Inc, Palo Alto, CA, USA). The rats were placed in a $^{13}$C/$^{1}$H volume RF coil, for transmission, and a $^{13}$C four channel array RF coil (receive-only), was placed over the kidneys (RAPID Biomedical GmbH, Germany). The temperature was maintained at 37 °C and respiration was monitored throughout the experiment. A $^{1}$H trueFISP (TE/TR 1.3/2.7 ms, flip-angle 30, FOV 6 x 6 cm$^2$, matrix 128 x 128) sequence was performed as a scout, followed by a $^{13}$C radial FSE sequence, matrix 64 x 256, bandwidth = 50 kHz, TE = 6.2 ms, TR = 2 s, 1 axial slice (20 mm) centered on one kidney (fig. 1). Data analyses included HYPR reconstruction of the radial acquired $^{13}$C MRI data [5], with zerofilling to 128 x 128 matrix, performed in Matlab (MathWorks, Inc., Natick, USA). The relaxation data were fitted in Matlab with a single exponential fit.

**Results:** The $^{13}$C radial FSE sequence showed the ability to obtain a high spatial resolution and high temporal resolution of hyperpolarized $^{13}$C urea in the kidney. The average $T_2$ obtained by fitting to the radial profiles was 200 ms, allowing $T_2$ mapping of hyperpolarized urea in the rat kidney. A high frequency systematic pulsation was observed in the $T_2$ data.

**Discussion and conclusion:** The $^{13}$C radial FSE sequence in combination with the HYPR reconstruction method, allow removal of $T_2$ effects ($T_1$ if an inverison recovery pulse is employed prior to the FSE train) or visualize motion, such as respiration or heart rate pulsation. We demonstarted that simultaneous $T_2$ mapping and distribution maps of hyperpolarized urea is useful to identify the urea distribution in the kidney and that we can investigate urea $T_2$ relaxation mechanism in vivo, as seen with lacatate and alanine [6]. The high frequency pulsation was most likely caused by pulsation effects from inflow of newly hyperpolarized urea.

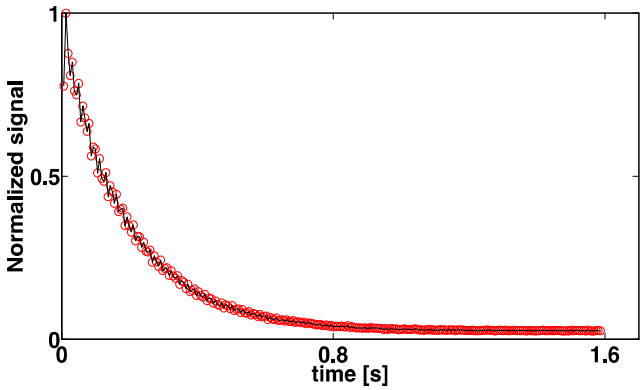


**Figure 2** $T_2$ relaxation during the echo train, showing the high frequency pulsation in the profile amplitude.

**References**

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